Before the
Federal Communications Commission, Washington, D.C. 20554

In the Matter of	)	
	)	
Unlicensed Used of the 6 GHz Band	)	ET Docket No. 18-295
ET Docket No. 18-295		
	)	
Expanding Flexible Use in Mid-Band Spectrum	)	GN Docket No. 17-183
Between 3.7 and 24 GHz	)	

Zebra Technologies, Inc. Comments in response to
Notice of Proposed Rule Making (FCC 18-147)

Zebra Technologies, Inc. is pleased to submit these comments in response to the Federal Communications Commission's Notice of Proposed Rule Making (NPRM) in the above referenced docket.

1. Background

Zebra Technologies, Inc. (Zebra) produces and deploys the Dart system (Dart), which utilizes ultrawideband (UWB) technology. Dart is a real-time locating system (RTLS) and is deployed into a variety of markets, including manufacturing, safety, and professional sports. Dart consists of small, autonomous, battery-operated, transmitting "tags", along with a set of receivers placed throughout a facility. Receiving infrastructure may be installed either indoors or outdoors. Typically, receivers covering an outdoor space are placed around a perimeter with antennas of modest gain facing toward the covered region. The location of the tags is determined to sub-1 ft accuracy by calculations based on the times of reception of short packet bursts from the tags at the various receivers. Dart tags are extremely power-efficient and can transmit continuously for several years at intervals of one second or even less.

Several thousand location events per second can be processed by a Dart system. The tags are certified under FCC part 15.250 and transmit spectrally-controlled impulses with relatively high peak and low average power. This is exactly what 15.250 encourages: one-way communication of short packets of very short pulses in both indoor and outdoor environments. Dart tags operate very near the peak power limit of 15.250 and are routinely tracked over distances of 600-1000 ft in open spaces.

1.2 Innovative Uses of Zebra's Dart Systems

Zebra's Dart systems are an integral part of production processes at numerous large industrial settlings across the United States. Dart is used for tracking thousands of tools at multiple airliner assembly facilities. Zebra's UWB solution is also used to ensure worker safety at 10 aircraft painting facilities, finishing dozens of commercial airliners each quarter. In yet another application, the production of 25,000 automobiles per month is streamlined by the tracking of more than 1000 different automated tools.

Additionally, Dart has been used for real-time player tracking in the National Football League (NFL) for the last five years. The system has been used for the last three seasons to track every player at every venue for every game. Dart tags are installed in all NFL player shoulder pads and footballs. The position data along with derived motion information has revolutionized professional football, by enabling in-depth performance analysis and live broadcast enhancement.

Dart is currently deployed in a wide variety of environments, ranging from totally indoor to totally outdoor, with many being a combination of both. Some NFL stadiums are fully enclosed, while others have large gaps in their perimeter walls. Dart is deployed throughout several NFL teams' practice facilities, all of which include outdoor areas the size of several football fields generally adjacent to commercial or residential neighborhoods. Industrial deployments typically span indoor and outdoor spaces.

1.3 How the Dart Systems Works

Zebra's Dart utilizes Impulse Radio UWB (IR-UWB) in its implementation. Dart's IR-UWB receivers have a large instantaneous bandwidth (greater than 400 MHz) centered at 6550 MHz. Dart RTLS is based on measurement of differences in arrival time at the various receivers and is optimized for measurement of earliest arrival of energy. In order to obtain long range and high accuracy, IR-UWB receivers operate with little margin above the full bandwidth noise floor. As a result, Dart receivers are very susceptible to narrowband interference anywhere in their passband. The existing situation has been very manageable because the incumbents operate either in consistent channels with narrow beamwidths (Fixed Service, or FS, in 5925-6425 MHz and 6525-6875 MHz), or otherwise only very infrequently and in well-defined bands (Mobile, from 6425-6525 MHz and 6875-7125 MHz). The instances of interference to Dart are few and far between and when they do occur the interference tends to be orderly and predictable. Due to that order, these cases can be managed by additional filtering and deployment of more receivers. However, this creates performance degradation and significant expense and is only justifiable in high-value deployments.

1.4 The NPRM's Proposed Power Levels and Spectral Allocations Would Severely Impact UWB Technologies

The NPRM[1] requests input from interested parties regarding the effects of the proposed rule changes on UWB functionality[2]. Zebra is concerned that unlicensed Wi-Fi deployments, especially at the power levels and spectral bands indicated in the NPRM, will lead to random harmful interference that would negatively impact UWB. The result could be that further investment in these large deployments would not be economically prudent, thus depriving several industries, and consequently the public, of the benefits of accurate RTLS.

We support efforts to effectively allocate precious spectrum. But we also urge the FCC to recognize that allowing for diversity of technologies provides a great benefit, and that UWB should remain a part of the "ecosystem"[3] by providing another avenue of "flexibility for innovators"[4] as described in the NPRM. Given that 15.250 is the only section within Part 15 which allows autonomous outdoor operation with wide instantaneous bandwidths at a useful power level, there is no other place to relocate. In Subpart F, 15.517 restricts operation to indoors, while 15.519 requires a two-way communications channel which would preclude low cost, small size, and long battery life.

[1] FCC 18-147
[2] NPRM, paragraph 72
[3] NPRM, paragraph 20
[4] NPRM, paragraph 21

There are many other companies producing devices utilizing 5925-7125 MHz under 15.250 or Subpart F. Applications are not limited to RTLS, but include radar, secure access, wireless microphones, and liquid level sensing. The supporting technologies have taken many years to develop and refine and are now being deployed extensively. These deployments have successfully coexisted with licensed users across the 6 GHz band for years and can continue to do so. Due to the low power limits and large bandwidth disparity, interference *to* licensed systems has been nonexistent.

An advocacy organization[5] was recently formed to promote standards, nucleate collaboration, and address regulatory concerns among many of these companies. Many of these entities have expressed a conservative approach to re-allocation[6] which Zebra fully supports. Zebra also recognizes the public's appetite for wireless connectivity and seeks a realistic balance of interests.

It is with these considerations in mind that Zebra suggests the coexistence strategies outlined below. These strategies are designed to reduce the likelihood of interference to a manageable level and allow multiple unlicensed technologies to share 5925-7125 MHz while continuing to protect licensed users.

2. Coexistence Strategies

There is such a large disparity between proposed Wi-Fi outdoor power levels and existing peak power limits under 15.250 that the future of UWB, with all its benefits, is at risk. The NPRM proposes EIRP levels of nominally 4W in U-NII-5 and U-NII-7. In contrast, a typical IR-UWB system operating at the peak spectral density limit allowed by 15.250 will have a full-bandwidth peak power on the order of 30mW.

This disparity will lead to a highly asymmetric situation. Furthermore, an IR-UWB receiver will suffer from narrowband interference at levels about 15dB below its peak, making matters worse. Even allowing for about 15dB of natural mitigation (terrain, obstruction, directionality), the range over which U-NII-5 or U-NII-7 access points operating outdoors at the proposed EIRP could blind an IR-UWB receiver is up to ten times its own operating range. Thus, a UWB deployment with a 600 ft range could be vulnerable to interference in U-NII-5 or U-NII-7 outdoor access point about 1 mile away. In order to get the interference distance comparable to the operating range of the UWB system, at the EIRP proposed in the NPRM, about 15-20dB of further mitigation will be required. Conversely, interference to Wi-Fi from UWB is essentially impossible, owing to the natural mitigation properties of wide bandwidth signals (Pulse Desensitization Correction Factor[7], or PDCF), coupled with the low spectral density limits of the existing Part 15.

The situation in U-NII-6 and U-NII-8 is much different, where the NPRM proposes 250mW with an indoor-only restriction. With some natural mitigation from walls, the resultant power levels will be comparable to UWB peak signals at distances comparable to the operating range. With the exception of mobile access points (covered below) typical physical separation will allow a high degree of coexistence in these bands.

The following outlines four ways to provide mitigation and create an environment in which multiple unlicensed technologies can share 5925-7125 MHz: Spectral limitation, power limitation, operational restriction, and exclusion beacons. A prudent combination of the four is also viable. The following

[5] https://uwballiance.org

[6] See ex-parte filing of UWB Alliance, October 18, 2018

[7] See HP Application Note 150-2, and 47 CFR § 15.35 (b)

suggestions assume that a facility can exercise control over its own environment and choose the appropriate technology for its own use but will generally have no influence beyond its perimeter.

2.1. Spectral limitation

The MOBILE NOW section of RAY BAUM'S ACT [8] only requires the allocation of 100 MHz of spectrum below 8000 MHz for unlicensed use. Allocating the lower 175 MHz (5925-6100 MHz) would satisfy the requirement while providing significant mitigation for UWB.

The mitigation derives from the implementation realities of UWB systems. In particular, the lower few hundred MHz of 5925-7250 are generally not utilized by UWB, especially those utilizing the provisions of 15.250. This is partly due to the spectral mask requirement at 5925 MHz, partly due to the desire to avoid devices in U-NII-3 (5725-5850 MHz) and U-NII-4 (5850-5925 MHz), but more significantly due to the properties of bandpass filters which tend to have wide "skirts" when designed for large instantaneous bandwidths, coupled with the general desire for compatibility with EU regulations which have a much stricter spectral mask (-30dB) at 6000 MHz. Part 15.517 devices which may utilize that portion of the spectrum are constrained to operate indoors, and so have mitigation from building walls, while 15.519 devices are generally intended for short-range, two-way operation[9].

The net result is that UWB receivers, especially those intended for long-range outdoor operation (and, hence, susceptible to beyond-perimeter interference) will generally include significant internal mitigation, through filtering, below 6100 MHz. This mitigation would allow a high degree of coexistence, even within a common perimeter.

Wi-Fi from 5925-6245 MHz as previously suggested[10] would provide significantly less mitigation but would still allow some degree of coexistence when significant spatial separation was possible. Future generations of UWB receivers could then offer improved rejection, previously not needed, and permit a higher degree of coexistence.

2.2. Power limitation

Another way to foster coexistence is to level the playing field in terms of allowed outdoor EIRP. In fact, 4W EIRP is a substantial field strength which does not promote spatial re-use among Wi-Fi access points. High density access is best accomplished with lower power. Other existing bands with higher allowed power levels can be used for Wi-Fi in low density situations which, by consequence of their low density, are generally not congested. Indeed, it can be argued that the congestion found in the existing U-NII bands[11] is caused in part by the high allowed power levels in those bands.

Zebra routinely demonstrates with Dart that an operating range of 600 ft is practical even with non-ideal tag positioning (NFL shoulder pads, for example). Although modest receiver gain is employed, the noise bandwidth of a Dart receiver is on the order of 400MHz. This strongly suggests that 30mW for outdoor Wi-Fi can cover a significant area, especially in dense areas where obstructions are already likely to limit range to a few hundred feet. In sparse regions, for which the potential for long-range interference is highest, other bands are available for Wi-Fi at high power levels.

[8] HR 1625, Division P, TITLE VI

[9] FCC 04-285 paragraph 97

[10] See ex-parte filing of Zebra, December 14, 2018

[11] FCC 18-147, comments of Commissioner O'Reilly, Commissioner Carr

Limiting outdoor U-NII-5 or U-NII-7 allocation to 30mW EIRP would encourage more efficient designs, cultivate spatial re-use, and encourage diverse use of the spectrum by making the interference range to UWB similar to the operating range of both systems. The odds of finding an access point which causes interference, to either Wi-Fi or UWB, will be roughly proportional to the area covered by the interference range, or R^2. Reducing that range will have a highly beneficial effect on spatial re-use and diversity of technologies. By leveling the peak power among the technologies, situations of interference to UWB would still be possible but they would be less frequent and much more likely to be correctable in the field. The situation would still be highly asymmetric, but it would be much more manageable.

2.3. Operational restrictions

Although the proposed U-NII-6 and U-NII-8 rules would restrict Wi-Fi in those bands to operate indoors, there is a concern regarding mobile operation. The NPRM wisely proposes prohibiting access points for all proposed bands from operating in moving vehicles[12]. The reasons given are the impracticability of a reliable AFC function in a dynamic situation for U-NII-5 and U-NII-7, as well as an expectation of minimal attenuation, when compared to building walls, for U-NII-6 and U-NII-8. Along those same lines, the NPRM requests comment on permissibility of mobile hotspots in U-NII-5 and U-NII-7[13].

Zebra favors such a prohibition and strongly believes it should be expanded to mobile hotspots in U-NII-6 and U-NII-8 as well. A mobile or transportable device may not be able to determine if it is indoors or out, and so could cause harmful interference to licensed services in those bands, as well as creating unpredictable and disabling interference to UWB deployments. For example, the UWB system in an NFL stadium could be easily disabled by a fan operating such a feature on their smartphone. Similarly, a contractor entering an industrial facility could render the RTLS system inoperable. These very real possibilities create a very large uncertainty which could easily lead to a reluctance to deploy or further develop UWB systems. Furthermore, mobile hotspot capabilities already exist in other bands available for Wi-Fi. Toward the goal of diversity of technologies, and a vibrant ecosystem, Zebra suggests that mobile hotspots be prohibited throughout 5925-7125 MHz.

The NPRM suggests the use of an AFC system for coordination[14] with licensed services operating in U-NII-5 and U-NII-7. One component of an unlicensed coexistence strategy would be to allow operators of UWB deployments to register in the AFC database a territory with some buffer zone around their own perimeter for the appropriate band of frequencies. The width of the buffer zone would be subject to the operating power level of the Wi-Fi access point. Although Zebra recognizes that such a zone beyond the operating perimeter may not be ideal, the asymmetry of interference potential creates a situation for which the public may best be served if such a registration were allowed in some cases.

Large industrial operations would have the greatest need for this sort of mitigation. However, these will often have surrounding parking lots and buffer zones of their own which will provide some natural mitigation and reduce the impact of AFC on their neighbors. However, it is easy to picture situations in which this would not be the case. For example, a hotel installing Wi-Fi on a patio might be located close to an NFL team's practice facility outfitted with outdoor UWB tracking. Many of

[12] NPRM, paragraphs 84-85
[13] NPRM, paragraph 76
[14] NPRM, paragraph 20

these cases can be expected to appear in low-density areas where alternate bands are available for Wi-Fi. Unlicensed participation in AFC would also provide mitigation against access points, whether fixed, mobile, or transportable, unexpectedly brought within the registrant's perimeter. Participation would be a particularly essential mitigation mechanism in case mobile access points are not entirely prohibited but are required to participate in AFC.

2.4. Exclusion Beacons

It is also possible to implement a more dynamic type of AFC, by which an access point would need to check for the presence of an "exclusion beacon" before commencing operation. The exclusion beacon would operate on another band available for Wi-Fi and would indicate which portions of the spectrum were to be avoided for Wi-Fi. While this could augment AFC in U-NII-5 or U-NII-7, it may also be appropriate for U-NII-6 and U-NII-8 where licensed mobile operations require dynamic coordination and where indoor operation may provide insufficient mitigation. Deployments by unlicensed entities could be controlled by a registration process to ensure justifiable use and minimal impact to adjacent space.

This provision would make for a self-organizing mitigation scheme, not unlike the avoidance mechanism implemented in some existing Wi-Fi systems for situations in which two proximal access points are deployed by separate entities. Implemented alone, it would avoid the need to coordinate with a database, and all the associated delays and sources of error. In conjunction with a database-controlled AFC, it would act as a back-up strategy for critical deployments in which the database was deemed unavailable, too slow, or too inaccurate.

3. Summary

The asymmetric nature of potential interference drives the need for a robust mitigation strategy to allow an ecosystem to exist, and the benefits of UWB deployments to flourish. In order to promote innovation and allow for the availability of diverse technologies, a strategy for coexistence must be included in any new rules. Constrained spectral extent for outdoor Wi-Fi, a compromise between high-power/low-density and low-power/high-density Wi-Fi operation, and certain operational restrictions can all be utilized to promote coexistence and diverse utilization of the 6 GHz band.

Zebra's suggestions can be summarized as follows, all driven by the highly asymmetric potential for interference:

1) Prohibiting mobile hotspots across all of 5925-7125 MHz: The risk of interference to all users, including licensed fixed and mobile, is too high.
2) Limiting peak power outdoor to 30mW: Encourages spatial re-use and avoids long-range interference.
3) Constraining outdoor Wi-Fi to the lower portion of U-NII-5: 5925-6100 MHz would provide 175 MHz of spectrum for Wi-Fi, while allowing a high degree of coexistence with alternate unlicensed technologies.
4) Allowing unlicensed participation in AFC and exclusion beacons: Provides additional mitigation mechanism and avoids unexpected on-site interference. Could be dynamic, organic, self-organizing via a beaconing approach.

There are, of course, combinations and variations of these suggestions that could provide for healthy coexistence[15]. By making these suggestions, and describing existing unlicensed use cases, Zebra seeks a rational compromise which will allow continued innovation, diversity, and provide the greatest benefit to the United States.

The power levels and spectral allocations proposed in the NPRM, coupled with the unpredictable deployment of unlicensed access points, will create changes to the RF environment that will have a devastating impact on some very important technologies. While Zebra appreciates the FCC's efforts to provide for more unlicensed use of the 6 GHz band, Zebra also recognizes the potential for jeopardizing the future of alternate innovative uses of the band should the rule making proceed unchanged. Zebra further appreciates the FCC's interest in coexistence among unlicensed systems[16]. Fortunately, some mitigation strategies could be implemented to allow a vibrant ecosystem to develop.

Respectfully submitted,
Zebra Technologies, Inc.
By:

Edward A. Richley

Carl S. Mower

February 15, 2019

[15] For example, 4 could displace 1 if AFC is required in all bands. Likewise, allowing Wi-Fi with higher power from 5925-6100 MHz and lower power elsewhere could provide for a nice variety of options.

[16] NPRM, paragraphs 20, 72